

USE OF WING TAGS AND OTHER METHODS TO MARK MARBLED TEAL (*MARMARONETTA ANGUSTIROSTRIS*) IN SPAIN

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SUMMARY.—*Use of wing tags and other methods to mark Marbled Teal (Marmaronetta angustirostris) in Spain.*

Aims: To design methods to mark Marbled Teal *Marmaronetta angustirostris*, to test these methods in captive conditions and to apply them in field research in Spain.

Location: Marked birds were released at El Hondo, Valencian community (eastern Spain) and Doñana (south-west Spain). Captive trials were conducted at nearby recovery centres.

Methods: Colour and Darvic rings, nasal markers and wing tags were tested in captivity. Various designs of wing (patagial) tags varying in shape, size, nature of the code and attachment methods were also tested. Nasal markers were rejected after most fell off within a month in captivity. The other methods were used to mark birds that were released into El Hondo (following their rescue when they became trapped in an irrigation channel) or Doñana.

Results: PVC colour rings stuck with superglue often dropped off within months, probably owing to the high temperatures. Especially designed Darvic rings with two digit alphanumeric codes were used, but these were rarely legible in the field. Initially a wider wing tag was used to mark 52 birds released in 1996, after testing with pinioned birds in captivity. It was then discovered that these tags caused feather wear on the opposing wing in full-winged birds, owing to the spinning of the tags during wing flapping. A narrower tag that greatly reduced this problem was developed and it was used to mark 288 birds released in 1997-1999. Observations of marked birds showed that most birds released at El Hondo remained there, although some were observed at Albufera de Valencia and Marjal del Moro. One bird was also recovered from Algeria. No birds released at El Hondo were recorded in Doñana, although one bird tagged in Doñana was observed at El Hondo. Tagged females in their first and second years were observed with broods, providing the first breeding observations for Marbled Teal of known age in the wild.

Conclusions: Wing tags provided much more data than rings, but there were major problems of tag loss, poor visibility and feather wear. They are most appropriate for intensive studies in the first few months after marking, and are not suitable for general use in this threatened species. El Hondo is likely to be the source for the recent expansion of Marbled Teal into Albufera de Valencia, Marjal del Moro and other valencian breeding sites. There is little connectivity between El Hondo and Doñana, the two main breeding areas in Spain.

Key words: colour rings, Doñana, El Hondo, Marbled Teal, *Marmaronetta angustirostris*, migratory movements, nasal markers, reintroduction, wing tags.

RESUMEN.—*Uso de marcas alares y otros métodos para marcar la Cerceta Pardilla (Marmaronetta angustirostris) en España.*

Objetivos: Diseñar métodos para marcar la Cerceta Pardilla *Marmaronetta angustirostris*, probarlos en cautividad, y usarlos en nuestra investigación en el campo.

Localidad: Se soltaron aves marcadas en El Hondo (Comunidad Valenciana) y Doñana (Andalucía). Las pruebas en cautividad se realizaron en centros de recuperación cercanos.

Métodos: Se hicieron pruebas con anillas de color, anillas de lectura a distancia (diseñadas a propósito, con códigos alfanuméricos de dos dígitos), marcas nasales y marcas alares (en el patagio) en cautividad. Se probaron varios diseños de marcas alares con distintas formas, tamaños, códigos y maneras de sujetarse. Se rechazaron las marcas nasales porque la mayoría se cayeron durante el primer mes en cautividad. Los otros métodos se usaron para marcar aves que se soltaron en El Hondo (después de ser rescatadas cuando quedaron atrapadas en un azarbe) o en Doñana.

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Resultados: Las anillas de color, pegadas con pegamento rápido, se cayeron a menudo en pocos meses, probablemente debido a las altas temperaturas. Las anillas de lectura a distancia muy pocas veces se pudieron leer en el campo. Al principio, se utilizó una marca alar ancha con 52 aves soltadas en 1996, tras probarlas con aves cautivas y mancadadas. Después, se averiguó que estas marcas causaron desgaste de las plumas del ala opuesta en las aves no mancadadas, debido al roce de las marcas durante el batir de las alas. En consecuencia, se diseñó una marca más estrecha que redujo este problema considerablemente, y se la usó para marcar 288 aves soltadas entre 1997 y 1999. Las observaciones de aves marcadas indicaron que la mayoría de los ejemplares soltados en El Hondo se quedaron allí, aunque se observaron algunos en l'Albufera de Valencia y en el Marjal del Moro. Un ave se recuperó en Argelia. Ninguna de las aves liberadas en El Hondo se observaron en Doñana, aunque en El Hondo se observó un ave marcada en Doñana. Se observaron hembras marcadas que tenían polladas en su primer o segundo año de vida, proporcionando las primeras observaciones en el campo de reproducción de cercetas pardillas de edad conocida.

Conclusiones: Las marcas alares proporcionaron muchos más datos que las anillas, pero hubo importantes problemas causados por la pérdida de las marcas, la poca visibilidad y el desgaste de las plumas. Las marcas alares son más apropiadas para estudios intensivos durante los primeros meses después del marcaje, y no son convenientes para el uso generalizado en esta especie amenazada. Es probable que El Hondo haya actuado como fuente de aves para la reciente expansión de la especie como nidificante a otros humedales valencianos como l'Albufera de Valencia y el Marjal del Moro. Hay poca conexión entre El Hondo y Doñana, los dos núcleos principales para la especie en España.

Palabras clave: anillas de color, Cerceta Pardilla, Doñana, El Hondo, *Marmaronetta angustirostris*, marcas alares, marcas nasales, movimientos migratorios, reintroducción.

INTRODUCTION

In order to design and carry out effective conservation programmes for threatened birds, it is often essential to mark individuals to facilitate monitoring and research. Various methods have been developed to mark individual birds, but some can have negative effects on behaviour or survival (see Calvo & Furness, 1992; Gaunt & Oring, 1997, for reviews). Amongst the Anatidae, geese are readily marked using Darvic rings fitted to the legs or necks. In contrast, neither method is very suitable for ducks since they have shorter necks and are usually in the water where the legs are out of view. Furthermore, their smaller size makes leg rings harder to read in the field. Thus, nasal markers (e.g. Arnold & Clark, 1996; Brook and Clark, 2002) and wing tags (e.g. Pöysä & Virtanen, 1994; Guillemain *et al.*, 2002) have often been used to mark ducks, although few authors have investigated the resilience of their markers and their effects on the birds, e.g. by detailed studies in captivity. Both nasal markers and wing (patagial) tags can have deleterious effects on survival or reproductive success of birds (Koob, 1981; Kinkel, 1989; Bustnes & Erikstad, 1990; Howerter *et al.*, 1997; Brua, 1998). For threatened spe-

cies or populations, it is particularly important to balance any potential risk from the impact of marking against the expected benefits.

The Marbled Teal *Marmaronetta angustirostris* is a globally threatened species (IUCN Vulnerable, BirdLife International, 2000) that has undergone a major decline across its range. Here the experience of marking Marbled Teal as part of a long term research programme in Spain, addressing important aspects of its biology (Green 1998; Green & Sánchez, 2003; Madroño *et al.*, in press), is reported. The aim of marking birds was the investigation of the interchange of individuals between different wetlands and subpopulations, the survival of birds released into the wild after rearing in captivity, sexual or seasonal differences in mortality rates, and habitat use of individual birds (e.g. movements of females during brood rearing). Most of the marking was done using wing tags. Details are presented here of the durability of different types of markers and their effects on the birds in captivity and in the field. Consideration is also given to how this marking programme has improved the understanding of the movements and breeding biology of Marbled Teal. Details of analyses of the survival rates of marked teal are presented elsewhere (GREEN, *et al.*, in press).

MATERIAL AND METHODS

Most Marbled Teal used in the field study were rescued as ducklings from 1994 to 1998 inclusive after they became trapped in a concrete irrigation channel (Navarro *et al.*, 1995; Green *et al.*, 1999) in the El Hondo wetland complex (38° 11' N, 00° 45' W; 1,650 ha) in the south of Alicante province within the autonomous community of Valencia in eastern Spain. El Hondo holds the majority of the European breeding population of Marbled Teal (Green, 1996; Green *et al.*, 2003) and is protected as a Natural Park, Specially Protected Area under the European Union Birds Directive, and Ramsar site (Bernués, 1998). Approximately a third of all broods became trapped in the irrigation channel until it was modified in 1998 by incorporating ramps. Large *Phragmites* reedbeds and problems of access to several of the privately owned wetlands complicate bird surveys. Marbled Teal are recorded there all year round but are more abundant from April to November inclusive (Navarro & Robledano, 1995). Broods hatch from early May to mid July (Green *et al.*, 1999).

After rescue, ducklings were taken to the Recovery Centre for Fauna in Valencia (Centro de Recuperación de Fauna de El Saler, CRFES from hereon). The teal were then reared in groups in the absence of adults, and were later marked, sexed by cloacal inspection and measured a few days before release in El Hondo. They were released either shortly after fledging or after the winter hunting season, which causes significant mortality of Marbled Teal at these and neighbouring wetlands (Navarro & Robledano, 1995). Following release, Teals were monitored by reading the codes on tags using telescopes.

Smaller numbers of teal were also marked prior to release in 1999 in Doñana, south-west Spain, the second most important area in Europe for Marbled Teal (Green *et al.*, 2003). These teal were either bred in captivity at the Cañada de los Pajaros in Sevilla (37° 14' N, 6° 09' W, CDLP from hereon), or rescued as eggs from the area of Doñana contaminated by a toxic mine spill in April 1998 (Grimalt *et al.*, 1999). These latter birds were reared in captivity at the Acebuche Recovery Centre (ARC from hereon) in Huelva (both sites in the Doñana area). All birds were released at Veta La Palma in Doñana Natural Park (36° 57' N, 6° 14' W).

Wing tag design

Prior to its use in the field, all marking methods were tested on captive-bred Marbled Teal at the CDLP to assess its effect on the birds and to perfect the attachment method. The initial design of wing tags used to mark teal released into the wild (called «large tags» from hereon) was 55 mm long with a 28 mm wide base (Fig. 1) and was influenced by the design used to mark Great Spotted Cuckoos *Clamator glandarius* (F. Alvarez, *pers. obs.*) and Azure Winged Magpies *Cyanopica cyanus* (C. de la Cruz, *pers. obs.*) in Spain. Trials on captive birds at CDLP showed that longer tags dipped into the water when birds were swimming, obscuring the code, whilst with shorter tags the code was usually covered by the upper wing coverts. The tag was made from heavy duty but flexible plastic-coated nylon fabric of the type used to make tarpaulins. A two digit alpha-numeric code was attached to the tag using sticky plastic digits (15 mm high). The tag surface was cleaned with alcohol before placing the code. A double layer of Ceys Vinilceys hardware glue was then placed carefully over the digits to seal them in place. Black digits on white tags were used on birds released in El Hondo. White digits on blue tags and black digits on yellow tags were used on birds released in Doñana. Alphanumeric codes used followed the standard codes used for ringing programmes (Calderón & Garrido, 1999).

The tags were attached by punching a hole in the patagium (Fig. 1), passing a nylon wire (1.6 mm diameter, similar to that used in grass trimmers) through the patagium and the tag, and fixing nylon disks (10 mm diameter, supplied by Bluemay Weston plc) at either side by melting the end of the wire and flattening it against the disk. Enough space (10 mm) between the disks was left to avoid them pressing tightly on the flesh of the wing. This attachment method allowed some freedom of movement of the tags around the axis of the disks, tending to make the tags hang down somewhat when birds were not flying, thus facilitating the reading of the code (Fig. 2). This is the reason why Anderson (1963) recommended a similar design. Further trials in captivity with a fixed attachment (similar to that of Weeks, 1972), passing part of the tag around the front of the wing and under the bottom disk (under



A



B

Fig. 1.—**A)** Wing tag of the larger size fitted to a full-winged captive Marbled Teal, showing the damage caused to the opposing wing after the tag had been fitted for several weeks (Photo: CRFES). **B)** Damage to the upperwing coverts of a captive Marbled Teal caused by a large tag attached to the opposing wing for 205 days (Photo: A. J. Green).

[*A*] Marca alar de gran tamaño fijadas al ala de una Cerceta Pardilla cautiva, mostrando el daño causado en el ala opuesta después de estar fijada durante varias semanas (Foto: CRFES). *B)* Daño en las cobertoras superiores en una Cerceta Pardilla mantenida en cautividad causadas por una marca alar que estuvo fijada en el ala opuesta durante 205 días (Foto: A. J. Green).]



Fig. 2.—Marbled Teal at El Hondo, marked with a wing tag of the smaller size. This female was rescued as a duckling on 8.7.97, released on 18.2.98 and photographed with a brood on 14.6.98 (Photo: M. Ferrández). [*Cerceta Pardilla en El Hondo con una marca alar de pequeño tamaño. Esta hembra fue capturada como paito el 8 de julio de 1997, liberada el 18 de febrero de 1998 y fotografiada con su prole el 14 de junio de 1998 (foto: M. Ferrández).*]

the wing) as well as under the top disk (on top of the wing), showed that this fixed tag position led the tags to be covered by the upper wing coverts, making the code very difficult to read. In addition, that part of the tag passing around the front of the wing inhibited the teal's normal wing-folding.

Initial trials on captive birds showed that immediately after tagging the birds would attempt to remove the tags. However, the birds apparently accepted the tags after the first few days, preening the tag without attempting to remove it. When rehandling marked birds, it was appa-

rent that, during the weeks following marking, tissue growth occurred in the patagium around the hole where the tag was inserted, producing a pronounced thickening of the patagium (expected) which appeared to be innocuous.

In order to assess the effects of the large tags on teal behaviour and tag durability, observations were made of pinioned teal in a large semi-natural lagoon at CDLP. After marking, visits were made at regular intervals and the tags were inspected by telescope. Birds that had lost their tags or their codes were identified using coloured leg rings (see below) or by re-

capturing the teal in a walk-in Wainwright trap and reading the metal rings. Time-activity data were collected by focal sampling on six days between 8.10.95 and 4.7.96, sampling each individual for five minutes and alternating where possible between birds with and without tags. Data were collected in the morning (0900 h - 1230 h local time) and late afternoon (1730 h - 2030 h). All birds were individually identifiable from colour ring combinations, and no individual was sampled more than once each day. The time spent preening wings was quantified separately to that spent in other comfort behaviours (see Green & El Hamzaoui, 2000, for definition). A total of 73 minutes data were collected from wing-tagged birds, and 91 minutes from untagged birds. Data were collected from 10 to 609 days after wing tags were attached (median = 90 days).

Large tags were used on birds released into the field in El Hondo in 1996, fixing the tags two days before release. However, unexpectedly, subsequent observations on full-winged birds in captivity showed that these tags often caused major feather wear on the upper wing coverts of the untagged wing (Fig. 1), because flapping the wings occasionally led the tag to lie upright from the disks (rather than downwards). Upon folding the wings, this led to the tag rubbing against the opposing wing. In extreme cases, this caused open wounds in the affected part of the wing. This led to the redesign of tags for future releases. After further trials at CDLP, the feather wear problem was almost eliminated by reducing the width of the tag to a maximum of 15 mm (Fig. 2), effectively reducing the ease of tag rotation around the disks when the wings are moved, owing to reduced tag mass away from the disk axis. Resistance to rotation was also increased by making the hole in the tag through which the cable passed as small as possible. A two digit code was still used but with digits of only 10 mm height, reducing the ease with which codes was read in the field. Since longer tags also had a greater tendency to rotate with wing-flapping, the length of the tag was also kept to the minimum (50-55 mm) necessary to have a readable code that was not continuously covered by the coverts that obscured the upper part of the tag (Fig. 2). These tags (called «small tags» from hereon) were used on all birds released from 1997 to 1999 onwards. However, significant

damage to the feathers of the opposing wing was observed after release in at least one bird, showing that this design did not completely eliminate the earlier problem.

Captive trials on pinioned birds showed that a small proportion of wing tags dropped or were pulled off shortly after release (see below), due to the weak method of sealing the disk position (intact tags were sometimes recovered in captive trials). Some tags came off the first days after release, when birds actively tried to remove them. Others dropped off later when exposure to high temperatures, light intensity and saline water weathered the nylon wire attachments. A larger proportion of tags became unreadable within weeks or months because part or all of the digits was lost (see below), no doubt due to the weathering effect of preening, wing-flapping, etc. Similar tags that were not attached to birds but placed in direct sunlight, rain and/or saltwater for three years remained intact, although a hardening of the digits after several months led them to crack when the tag was bent. Alternative methods of marking the code were tried without success. PVC paint used successfully to mark codes at the Wildfowl & Wetlands Trust, UK rubbed off within weeks on captive teal, probably because of the high summer temperatures in Spain. Screenprint (serigraphy) methods used to make T-shirts are used to make durable wing-tags for Azure-winged Magpies (C. de la Cruz, *pers. obs.*). The same marking method was tried but the teal removed many of the codes within a few days of marking (see below), probably because of the more abrasive action of the teal bill when preening the tag.

Leg rings and nasal markers

To identify captive teal at CDLP from a distance, individual combinations of coloured PVC leg rings (9 mm internal diameter), stuck with superglue, were used. A single coloured ring was also placed on teal released in El Hondo and other wetlands from 1994 to 1995, prior to use of wing tags. Different colour and leg combinations distinguished each date and location of release, but did not permit identification of individual teal (Navarro *et al.*, 1995; Green, 1997). Monitoring of captive teal marked with PVC leg rings stuck firmly with su-

perglue showed that many of these rings came unstuck and some fell off with time.

The need for individual combinations led to the use of small Darvic coded rings manufactured at the EBD (15 mm high, with a single code of two digits of 12 mm height, designed by the Equipo de Seguimiento de Procesos Naturales). These Darvics have an oval-shaped cross-section (internal diameter 7 and 11mm on the short and long axes) to provide a snugger fit to the tarsal bone and to facilitate correct positioning of the code for reading. From 1996 onwards, light blue rings with a black code were used on birds released at El Hondo (including those fitted with wing tags), and white rings with a black code or black rings with a white code on birds released in Doñana.

Trials with nasal tags used to mark Green-winged Teal *Anas carolinensis* in North America (the design of Lokemoen & Sharp, 1985, with separate nylon markers on either side of the bill) were conducted at CDLP. Three tags fitted on 28.9.95 were still attached after 10 days, but the two tags fitted with a steel pin had come off within 36 days. The remaining tag (with a nylon pin) was removed by us after 47 days. Of four tags fitted with nylon pins on 3.11.95, two had fallen off after 11 days, when the other two were removed. The tags were removed because they apparently caused breathing difficulties and internal bleeding. Owing to these problems, the low durability of the markers, and because use of nasal markers seems likely to interfere with mate choice in this species in which head displays are particularly important (Cramp & Simmons, 1977), it was decided to abandon nasal markers as a method for Marbled Teal. Nasal tags with nylon pins fitted to Ferruginous Duck *Aythya nyroca* bred at ARC and released in Doñana (Madroño *et al.*, in press) were found to drop off shortly after release (P. Pereira, *pers. obs.*).

RESULTS

Captive trials of wing tags

During trials conducted at CDLP, three of four pinioned teal marked with large tags on 27.9.94 were still tagged on 26.5.95 (after 241 days), but none of their codes (written on with white PVC paint) were legible. These birds

were still tagged on 4.7.96 (after over 21 months). In trials using large tags marked with single plastic digits of 28 mm height, of 12 teal marked (11 between 13.9.95 and 3.11.95, one on 8.5.96), all tags were intact after 11 days and at least 11 were intact after 36 days. One came off after 36-120 days, two were removed by us after 47 and 68 days, and one bird (the only one not pinioned) was last seen after 42 days then disappeared. The remaining 8 teal were still tagged after 243-294 days (on 4.7.96), but by then only two had intact codes. The other six had lost part or all of their codes during intervals between inspections after 11-124, 42-47, 47-131, 47-132, 186-207 and 246-282 days respectively. Large tags with two digit adhesive plastic codes used to mark six fully-winged teal on 23.7.96 were all still intact on 17.2.97 (after 205 days). At this point, all six birds were found to have feather damage on the unmarked wing (Fig. 1b) and the tags were removed.

Thus, for large tags with adhesive plastic codes, all of the 17 tags that could be evaluated for a period of 30 days retained legible marks. Of a total of 15 tags that could be evaluated for a period of 132 days, 10 (67%) of them remained legible. However, this includes the tags on the six full-winged teal that were kept in a small, shady pen where the tags were exposed less to sunlight and water than those of the pinioned birds in a large lagoon. Of nine tags on birds in the lagoon that could be evaluated for a period of 132 days, only four (44%) remained legible.

Time-activity data were used to compare % time spent in comfort behaviour between birds with large tags and those not tagged (comparing means for tagged and untagged birds for each day with a Wilcoxon matched-pairs test). There was no significant difference between tagged (mean \pm SE = 21.7 \pm 6.18) and untagged birds (mean \pm SE = 30.3 \pm 10.3) in % time spent in comfort (n = 6 days, T = 9.0, P = 0.80). Neither was there a difference in % time spent preening the wings (tagged birds: 12.6 (4.1); untagged birds 7.9 (4.1; T = 5.0, P = 0.50).

On 30.7.98, 16 fully-winged teal were marked at the ARC with small blue tags made by screenprint. After 35 days, no tags were lost but only 9 (56%) were still legible. On 15.10.99, 22 fully-winged teal were marked at

CDLP with small tags with plastic adhesive codes. After 55 days, 2 tags (9%) had come off but all remaining tags were legible.

Field data from marked birds

Marbled Teal rescued as chicks in 1996 ($n = 53$) were marked with large tags and released at El Hondo on 12.9.96. Of these, 21 teal were observed at El Hondo after the release day, but only 12 were seen more than a month after release. In total, tagged birds were identified on 36 occasions. One of them was found dead. Observations were often made of marked birds whose tags were unreadable because they had lost part or all of their codes. However, no birds with large tags were recorded after 28.4.99. The last observation when the code was read was 6.6.97.

Marbled Teal rescued as chicks in 1997 ($n = 44$) were marked with small tags and released at El Hondo on 18.2.98. Of these, 29 were observed after the release day, but only 9 were seen more than a month later. In total, tagged birds were identified on 40 occasions.

Marbled Teal rescued as chicks in 1998 ($n = 159$) were marked with small tags (38 made by screenprint, the rest with sticky plastic digits as in 1996 and 1997) and released at El Hondo between 31 July and 15 September 1998. Of these teal, only 22 were observed after release and only 18 were seen after more than a month. In total, tagged birds were identified on 41 occasions. Three of them were found dead. No birds with small tags used in 1998 were recorded later than 16.6.00 (when the code was still legible).

Observations of these birds at El Hondo and of 85 wing-tagged Marbled Teal released in Doñana in 1999 suggest that the marked birds integrated into flocks of wild teal and used the same habitat types as the fully wild teal. They showed no obvious behavioural differences except a reduced tendency to be disturbed by the presence of humans. Of birds released in Doñana, at least seven returned immediately to the CDLP where they had been reared (M. Adrián, *pers. obs.*, 1999). Other observations of Doñana birds ($n = 10$ where the code was read successfully) were limited to the Doñana National and Natural Parks, and the Brazo del Este (combined total area of *ca.* 150,000 ha). The

last observation was made on 29.9.00. No birds from Doñana were observed at El Hondo or vice versa.

However, one captive-bred female marked with a large tag (white code on blue plastic) at CDLP that escaped on 17.2.97 (one of two escapees) was observed in El Hondo 450 km away on 15.4.97 and then four more times in April, June and August until it was found dead during a waterbird mortality on 18.9.97. This total of five observations in five months at El Hondo (note the white code 02 was not completely read on at least one of these occasions) represents a particularly high number of re-sightings for a marked bird. Since this was the only blue tagged bird in the area, it was particularly likely to be identified.

No birds released at El Hondo were observed outside the Valencian Autonomous Community, with the exception of one bird released on 24.3.95 (rescued at El Hondo as a duckling on 8.6.94) that was recovered (shot) 530 km away at Djelfa, Algeria (34°43'N, 03°14'W) on 20.3.97. A small number of teal were observed at other Valencian wetlands 120-160 km to the north, as follows. One bird of unknown sex released at El Hondo in 1998 was observed at Racó de l'Olla (39°20'N, 00°21'W) in Albufera de Valencia attending a brood on 14.7.99. Two males released at El Hondo on 18.2.98 and 16.9.98 (code FP) were seen at Racó de l'Olla from 20.4.99 to 25.5.99. FP was also recorded at Marjal del Moro (39°38'N 00°15' W) on 30.4.99 in between the observations at Racó.

In addition, releasing of birds marked with coloured and coded leg rings in previous years led to some observations away from the capture-release site. One bird released at El Hondo on 26.7.95 and marked with a colour ring was observed at Marjal del Moro on 2.9.95 (Yuste, 1995).

From a total of 262 birds wing-tagged and released at El Hondo, only four were recovered dead. Only in one case was a Darvic ring read on a teal that had lost its wing tag (a female rescued on 10.6.97, released on 18.2.98 and observed on 29.5.98). Of the 85 tagged teal released in Doñana, only one was recovered dead. No leg rings were ever read there.

Observations of marked birds at El Hondo confirmed that wing-tagged females could successfully rear broods in the first and second ye-

ars after they hatched. One tagged female rescued and released in 1996 was observed with a brood of 6 ducklings on 20.6.97. Another tagged female rescued on 8.7.97 and released on 18.2.98 was seen with 7 class Ia ducklings on 14.6.98 (Fig. 2, see Green, 1998, for details of age classes). The same day, a female rescued on 18.5.96 and released on 11.2.97 was seen with 8 class Ic chicks. Another female rescued on 19.06.96 and released on 11.02.97 ringed but not fitted with a wing tag was seen with 6 (Ia) ducklings on 14-16 June 1998. Another female rescued on 3.7.98 and released on 16.9.98 was seen with 8 class II chicks from 10.6.00 to 18.6.00. Thus, overall two females were seen with broods in the first year after hatching, and three in the second.

DISCUSSION

Given the evidence of deleterious effects of marking with wing tags from captive studies (Fig. 1) and from previous studies in other birds (Kinkel, 1989; Bustnes & Erikstad, 1990; Brua, 1998), and problems with their durability, these are not recommended for general use with this or similar threatened duck species. Feather damage caused by the large wing tags was detected when full-winged birds were marked in captivity. This experience shows how conducting trials on pinioned birds in captivity can give misleading results. It is suggested that trials with full-winged birds in large aviaries should be carried out to assess such marking methods before their application in the wild. Use of wing tags in other species has usually not been accompanied by such captive trials or by detailed studies of their effects in the field (e.g. Pöysä & Virtanen, 1994; Guillemain *et al.*, 2002). When it is important to minimise any risk to the birds, conventional ringing is most appropriate and can be supplemented by the use of coloured and coded Darvic rings in cases where ducks can be studied by telescope, especially in small wetlands with sparsely vegetated islands where rings may be readily observed.

Feather wear and abrasion of the skin has sometimes been reported on the marked wing in studies of other bird families using wing tags (Kochert *et al.*, 1983; Hart, 1987; Calvo & Furness, 1992). As far as is known, the damage to the opposing wing observed with the trial tags

has not previously been reported in any studies, and there are no previous reports of feather wear in ducks. No such problems have been reported from Azure Winged Magpies marked with a similar tag design (C. de la Cruz, *pers. obs.*). This supports previous suggestions that wing tags cause more problems to species with faster wing beats (Kochert *et al.*, 1983) such as small ducks. While a cautious approach to the use of wing tags is recommended, they may be more successful on other duck species in more open habitats and with slower wing beats. Likewise, tags of the designs discussed apparently have more durable codes when used in regions with lower temperatures. Similarly, in northern Europe, PVC rings stuck with superglue remain stuck (C. Mitchell, *pers. obs.*), yet the high temperatures in Spain cause them to come unstuck.

Casual observations suggesting that wing-tagged birds behave normally and can breed successfully can not be taken as good evidence that the tags have no significant impact on the bird survival and life-time reproductive success. A detailed comparison of wing-tagged and untagged birds is necessary to assess the impact of tags on behaviour, mating success and survival (Kinkel, 1989; Bustnes & Erikstad, 1990; Brua 1998). Unfortunately, there is not enough data to enable such a comparison for Marbled Teal. Tags must increase drag of the wings and thus the energetic cost of flight. This may reduce flight speed or the time spent in flight. Tags may also increase the rate of predation or hunting mortality (Saunders, 1988; Szymczak & Ringelman, 1986). Although the Marbled Teal is a protected species in Spain, it is frequently shot (Navarro & Robledano, 1995) and tagged birds have been shot both at El Hondo and in Doñana, although total numbers are unknown.

As expected, wing-tagging Marbled Teal provided many more resightings than using coded leg rings. However, the total number of observations of tagged birds was lower than was hoped for. This is largely a reflection of the high rate of loss of legible tags, high mortality rates for this species (Green, 2000) and the difficulty of reading the tags under field conditions, for example, due to the large size of the wetlands, the abundance of emergent vegetation and the active, nervous behaviour of Marbled Teal.

The number of resightings was also reduced by the loss of legible tags. The loss rates of tags in the field, where birds fly more, may exceed those recorded in our captive studies, even those on full-winged birds. It is expected that more than half the tags of any design became illegible or dropped off within six months, perhaps within three. It would have been much easier to estimate the rates of wing tag loss if both wings had been tagged (Mudge & Ferns, 1978), but this would have increased the impact of marking on the birds.

Even taking into account the likely loss of tags, the number of observations of tagged birds was disappointing. A unique opportunity arose during the rescue operation to mark a large number of birds, which is not likely to be possible again. In order to carry out an effective study with this tag design, a larger team of people dedicated to looking for marked birds would be needed and greater access to the study area. These tags are most suitable for short term intensive studies, e.g. over the three months following release. The main problem that remains unsolved is how to attach a durable code. A more durable attachment method for the tag itself is also desirable. However, although with the current design a bird is likely to be able to remove the tag after persistent attempts, this may be an advantage since a stressed bird can remove the source of discomfort.

Although small numbers of Marbled Teal in Spain continue to become available for marking most years (e.g. sick birds taken to CRFES then released after rehabilitation), wing tags are no longer used as it is not considered that the potential risks involved are justified by the small number of resightings. Given the small size of the Marbled Teal and its use of large, densely vegetated habitats that make observation of marked birds difficult, radio-tracking may be the only way of obtaining detailed data of individual movements and survival (see Kenward, 1993; for a similar problem with raptors). However, the experience of radio-tracking breeding teal at El Hondo shows that the limited range of suitable transmitters and the large home ranges of teal again make collection of good data impractical without a large team of observers (authors, *pers. obs.*).

The observations of marked Marbled Teal away from release sites provided important in-

sights into the population processes in this species, which shows major fluctuations between years in population size at different wetlands (Green & Navarro, 1997; Madroño *et al.*, in press). Use of wing tags provided the first confirmation that rescued and released Marbled Teal breed successfully in El Hondo, and the first proof that females breed in the first year, as recorded in captivity (Cramp & Simmons, 1977). The movement of birds from El Hondo to Marjal del Moro and Racó de l'Olla suggests that the former site is the source of birds for the recent expansion of Marbled Teal into these and other new breeding sites in the Valencian region since 1992 (Green & Navarro, 1997; Madroño *et al.*, in press). In contrast, the absence of observations of birds released at El Hondo in Doñana suggests that birds breeding in eastern Spain make little use of Doñana. Most Marbled Teal breeding at El Hondo appear to winter in North Africa (Navarro & Robledano, 1995), as suggested by the recovery from Algeria. It seems likely these birds cross directly to Algeria from eastern Spain, instead of passing first through Doñana which is much closer to Africa. Large flocks of Marbled Teal that are too large to be the sole product of the local breeding population are often recorded in Doñana in autumn and early winter. The absence of birds marked at El Hondo (e.g. amongst the 594 birds observed in Doñana on 27.10.98) suggests that these flocks are likely to arrive from Moroccan wetlands (Green *et al.*, 2002). On the other hand, one bird was recorded moving in the opposite direction from CDLP to El Hondo. Similarly, a Marbled Teal ringed before fledging in Doñana in July 1968 was recovered that September in the Albufera de Valencia (Navarro & Robledano 1995).

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